

A central circular diagram with a reactor core icon in the middle. It is surrounded by eight smaller circles, each containing a different icon: a padlock, a test tube, a brick wall, a bell, a camera, a gauge, a pencil, and a test tube. Lines connect these outer circles to the central circle. The background features a large, stylized, multi-colored arc (green, yellow, orange) on the right side.

ADVANCED REACTOR SAFEGUARDS

ARS Program Overview & Accomplishments

PRESENTED BY

Ben Cipiti

ARS Spring Meeting, April 18-20, 2023

SAND 2023-02096PE, Sandia National Laboratories is a multimission laboratory managed and operated by National Technology and Engineering Solutions of Sandia LLC, a wholly owned subsidiary of Honeywell International Inc. for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

Working Group Meeting Goals



The Advanced Reactor Safeguards (ARS) program focuses on addressing near-term challenges advanced reactor vendors face in meeting U.S. domestic Physical Protection System (PPS) and Material Control and Accounting (MC&A) requirements.

Goals for this meeting:

- Present progress on technical work.
- Discuss collaboration within the program.
- Discuss external collaboration with vendors, stakeholders, and related program areas in DOE NE and NNSA.
- Plan work for FY24 and outyears.

Outreach & Impact



- We've established a quarterly call with the NRC on MC&A and a monthly call on physical security.
- We're expanding vendor partnerships through additional requests:
 - TP Natrium, TP MCFR, Westinghouse eVinci
 - Current requests from Kairos and X-Energy
- We continue to work collaboratively with NNSA on vendor partnerships (where there have been requests for both domestic and international support).
- The ARS website has been useful for circulating the UUR reports from the program:

<https://energy.sandia.gov/ars>

Outreach Observations



- The advanced reactor vendors are all in very different positions for technical approaches, deployment strategies, and technical maturity.
 - As a program, we need to continue to be flexible with vendors and partnerships depending on their needs.
- We are seeing how safeguards and security by design is also being addressed differently across the vendor community, and there remains a need to continue to promote the value of SSBD.
 - Some vendors are very receptive.
 - Others have difficulties presenting this need to their upper management.
 - There are also differences whether vendors plan to be owner/operators.
- Our interactions with NRC have been very positive, and it seems to really help NRC staff when they see the proposed concepts and approaches ahead of time.



- We've been able to get approval for presenting 5 papers and two panel sessions to the INMM/ESARDA meeting in Vienna (May 22-26):
 - Alan Evans: "Security By Design for Advanced and Small Modular Reactors"
 - Phil Gibbs: "Statistical Approaches for Pebble Bed Reactor Operations and Safeguards"
 - Mark Croce: "Characterization of Dissolved High-Burnup Nuclear Fuel with Microcalorimeter, High-Purity Germanium, and Cadmium Zinc Telluride Gamma Spectroscopy"
 - Nathan Shoman: "Novel Strategies for Safeguarding Molten Salt Reactors"
 - Odera Kim & Yonggang Cui: "Modeling and Simulation of Fuel Burnup in Pebble Bed Reactors"
 - Lap Cheng & Ben Cipiti (Panel) "Generation-IV Proliferation Resistance and Physical Protection: Transitioning from R&D to Deployment"
 - Ben Cipiti, Alan Evans, Claudio Gariazzo (Special Session) "Safeguards and Security by Design for Advanced Reactors: An Interactive Experience"
- We want to strongly encourage submission of ANS Summaries to the Advances in Nonproliferation Policy Technical Conference (ANTPC), embedded in the Winter ANS meeting in DC (November 12-15)



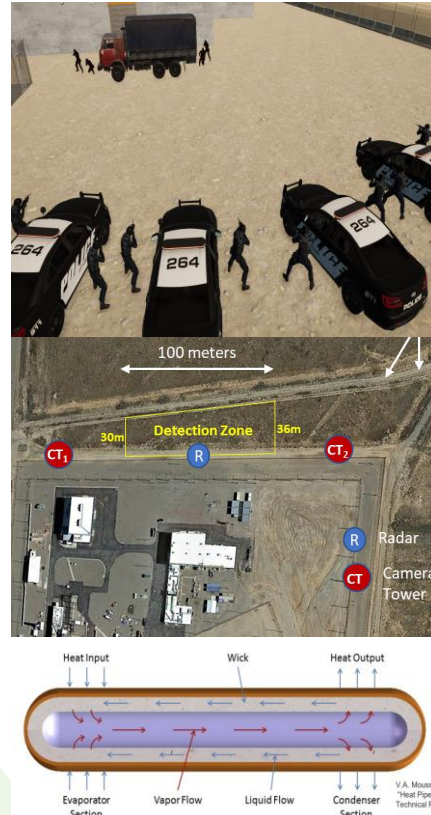
- Everyone in the program needs to put themselves in the shoes of the vendors when writing your final report – what does the vendor community take away from this?
 - If the report is more than 30-40 pages, need a good executive summary (NOTE that an executive summary should not just be a slightly longer abstract—you want to highlight your key technical results and include some figures/tables).
 - Have you provided results or performance testing to prove the use of the approach or technical concept?
 - Have you clearly articulated why this is important?
- In the traditional technical report structure, it often takes a long time to get into the “meat” of the report. Think about how to condense down intro, background, procedures sections to get to the main points/key results sooner.



- Monthly PICS status is important for program tracking—these inputs all roll up to a report to DOE NE.
 - Normally we want to see an input in accomplishments every month.
 - If you didn't spend any money, it's okay not to input accomplishments.
- Our main challenge with the budget is the monthly or quarterly distribution of money—we all need to take that into account when planning spending and any contracts.
 - If you do need to make a big purchase, let us know so we can adjust the lab allocations.
- International Travel Requests – DOE NE needs to see detail in these requests. In the future, note that there should be a good paragraph for both the Purpose/Scope and Justification tabs. These should be submitted when ARS work is involved, even if funded from another source.

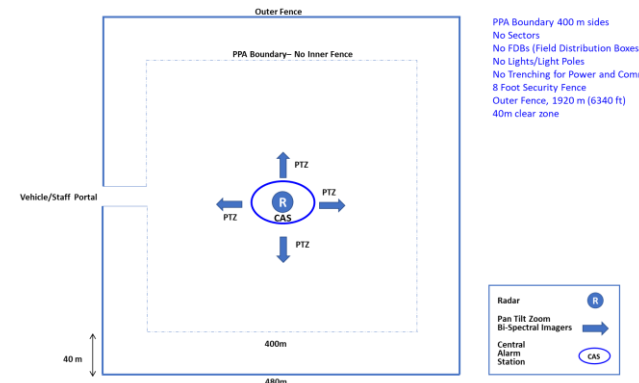
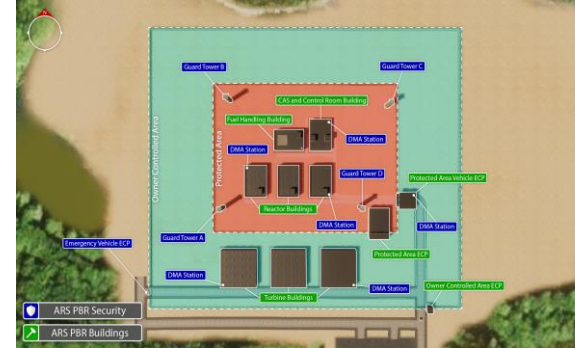
- Reduce number of on-site responders
- Reduce upfront costs
- Evaluate enhanced safety systems
- Evaluate unique sabotage targets

2 Years Ago



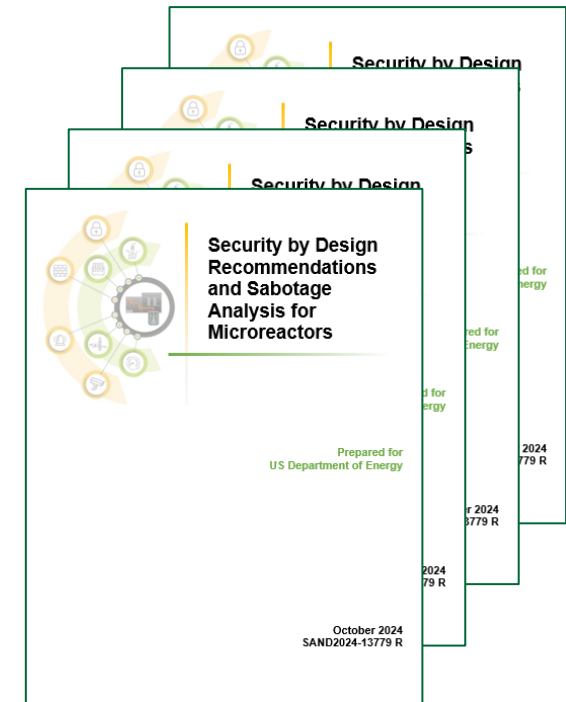
Evaluated enhanced delay features for reliance on off-site response, DMA technology, unique sabotage targets for advanced reactors

Where are we now?



Developing PPS options for vendors (Micro vs. SMR & on-site staff vs. ROWS options), DPIDS design, cyber-physical attacks (**M2**), separate reports on SFR, heat pipe, and HTGR sabotage analysis.

Where are we going?



PPS design recommendation report
for each class of advanced reactor
including sabotage, cyber, and
timeline analysis, DPIDS with
integrated UAS detection,

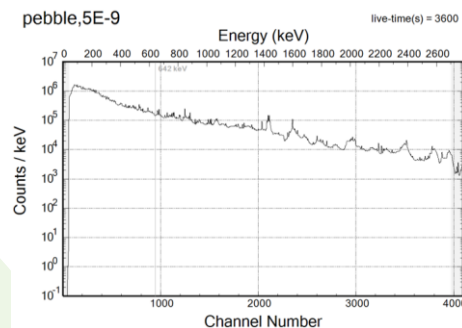
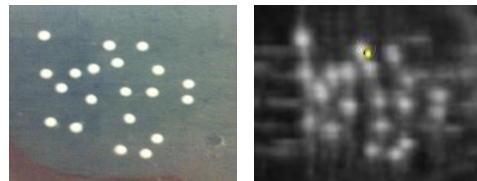
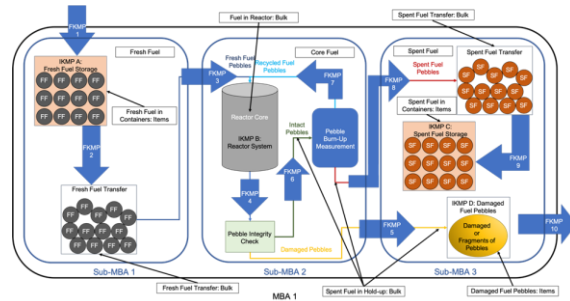
FY22-23 Thrust Areas: Highlights



Pebble Bed Reactor MC&A

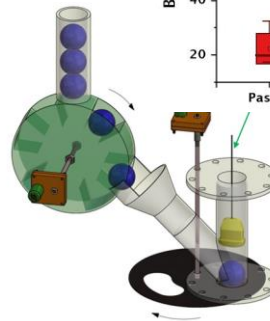
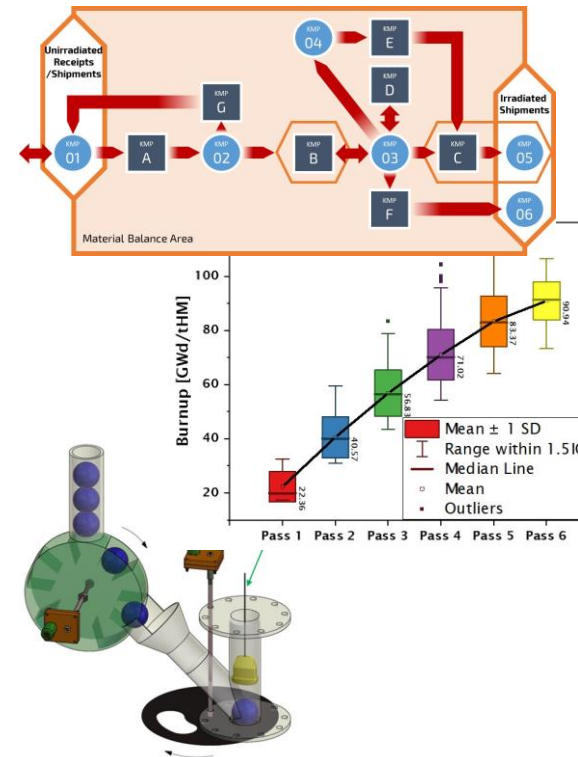
- Evaluate regulatory approach
- Determine driving requirements
- Evaluate new monitoring technologies

2 Years Ago



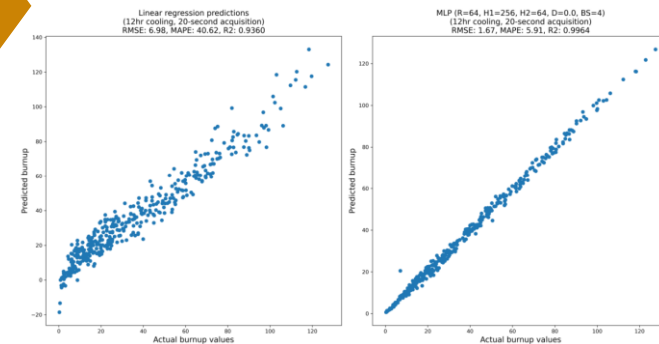
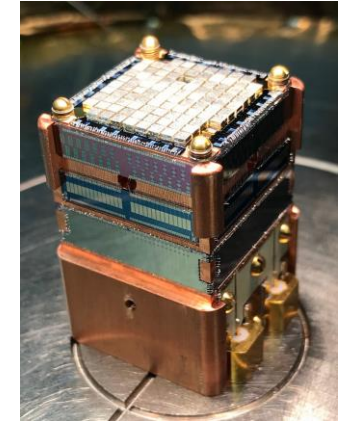
Developed a baseline MBA structure, and began evaluating pebble batch identification and improved burnup measurements

Where are we now?



Developing a pebble database, progressing pebble batch measurements, ML approach for improved burnup measurements, and tying all together into an integrated MC&A approach (**M2**).

Where are we going?



Complete an NDA measurement campaign for short-cooled pebbles and validate ML burnup measurement approach.

FY22-23 Thrust Areas: Highlights



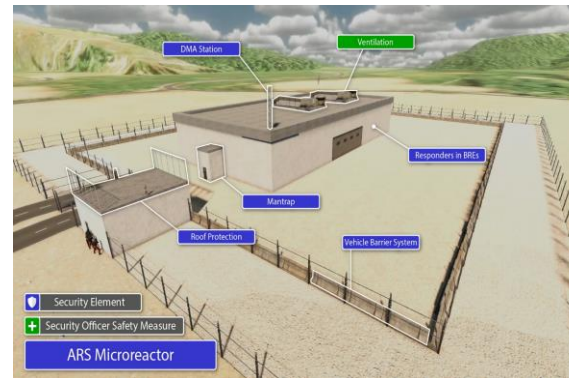
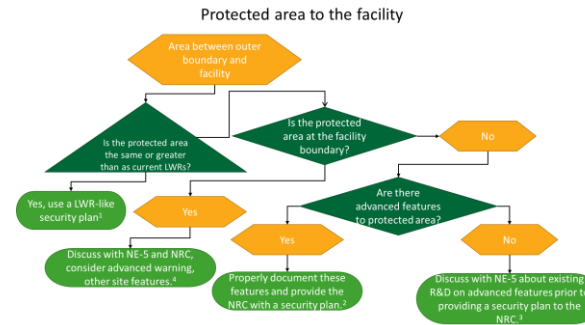
2 Years Ago

| Reactor concept | Residence | Core Features | Safety Features |
|---|---|--|---|
| Metallic-fueled, heat-pipe cooled, stationary reactor | • One location for its entire life cycle | • May or may not be sealed core • Possible need to rearrange fuel | • Secondary structures expected • Below-grade siting |
| TRISO-fueled, heat-pipe cooled, mobile reactor | • Multiple locations for an unspecified amount of time at each location | • May be sealed core • Onsite refueling will not be pursued | • Reactor in a mobile-at-will or mobile-at-ready operational mode • No additional, onsite infrastructure |
| TRISO-fueled, gas-cooled, mobile reactor | • Multiple locations for an unspecified amount of time at each location | • May be sealed core • Onsite refueling will not be pursued | • Reactor in a mobile-at-will or mobile-at-ready operational mode • No additional, onsite infrastructure |
| TRISO-fueled, gas-cooled, stationary reactor | • One location for its entire life cycle | • Most likely a sealed core • Cartridge refueling swap | • Secondary structures expected • Below-grade siting |



Evaluated different classes of microreactors and potential monitoring technologies for MC&A

Where are we now?



Lesser MC&A challenges have given way to enhanced emphasis on developing compact PPS design options.

Where are we going?



Develop multiple PPS options for vendors (above ground vs. below ground, with ROWS and without, enhanced delay), and assist universities with PPS requirements for university microreactors.

Microreactor PPS and MC&A

- Develop a licensing framework
- Develop approaches appropriate to the very small scale
- Evaluate new monitoring technologies

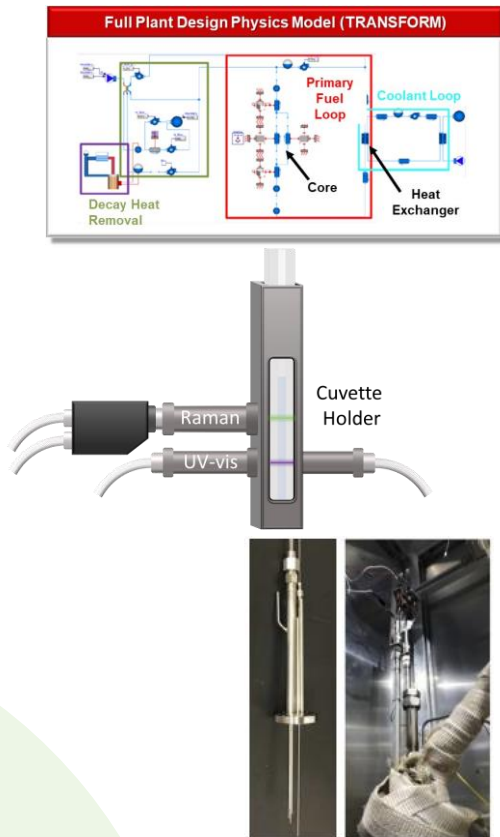
FY22-23 Thrust Areas: Highlights



Liquid Fueled MC&A

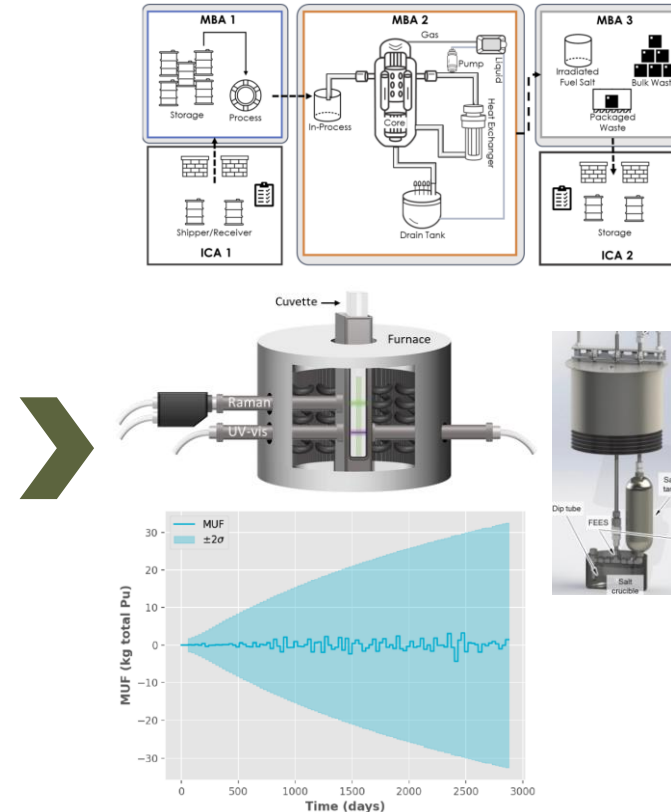
- Evaluate regulatory approach
- Develop baseline accountancy approaches
- Evaluate new measurement and monitoring technologies

2 Years Ago



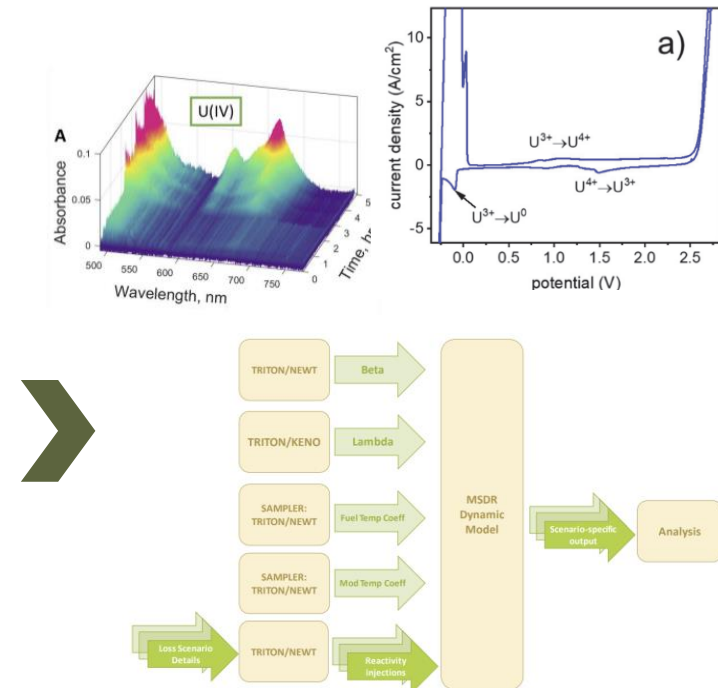
Starting to understand the various types of MSRs, modeling tools, and measurement technologies available for MC&A

Where are we now?



Developed a MBA/ICA structure (M2), understand better measurement limitations, developed the MFIT test bed, partnerships with vendors to test measurement technology.

Where are we going?



Develop an MC&A approach with integrated process monitoring, move measurement technologies toward pilot demonstration

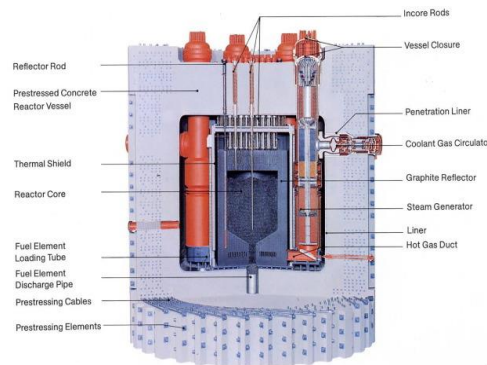
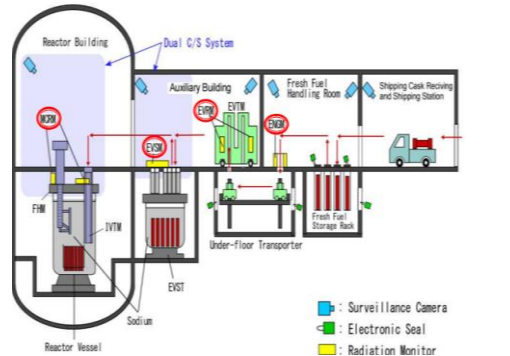
FY22-23 Thrust Areas: Highlights



International Considerations

- Consider international safeguards requirements
- Interface with NNSA programs
- Support the Gen-IV PR&PP working group

2 Years Ago



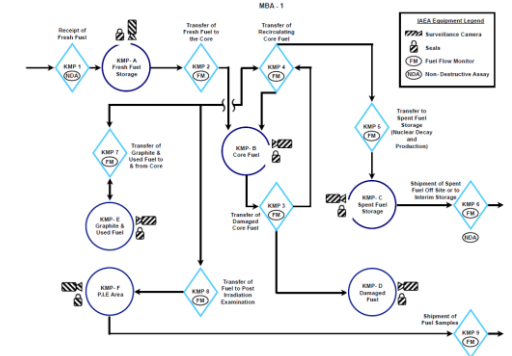
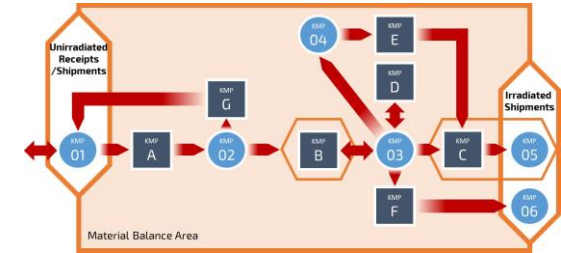
International safeguards case studies were evaluated to pull any lessons learned, Gen-IV PR&PP group working on PR&PP white papers

Where are we now?



Strong interface with NNSA program, the Gen-IV PR&PP group has released 5/6 AR system white papers and a companion crosscut document, evaluating potential joint use equipment.

Where are we going?



Continue to use ARS domestic results to help inform international safeguards approaches, respond to Gen-IV industry requests on siting, floating reactors, and 3S.

FY22-23 Thrust Areas: Highlights



2 Years Ago



Initially focused on a stakeholder workshop to understand vendor challenges better.

Where are we now?



We currently have 3 engagements with potentially 2 more. An AR Security Workshop was held in October, 2022.

Where are we going?



We expect to expand engagements as generic work starts getting applied with the vendors.

Vendor Engagements

- Design-specific MC&A and PPS challenges.
- NNSA partnerships
- Translate to lessons learned or generic deliverables.



- Our funding profile has stayed mostly flat, but we've been having more vendor requests that could use more money.
 - The FY 24 request is for \$6M (+\$1.25M, but it's too early to tell if that will be approved). We'll be developing an IPL for a range of scenarios.
- The work is performance-based, and we expect to rotate through projects as milestone reports are completed.
- We may see more shifting of generic work to applied work with vendors, but we do need to maintain open collaboration as much as possible.